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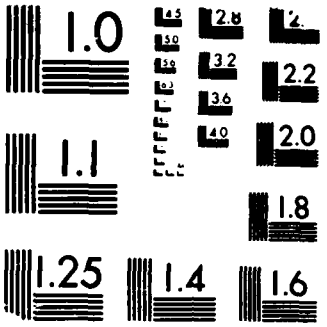

MICROCOPY RESOLUTION TEST CHART

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R.W. Nolan, C.W. Gibson* and S.D. Livingstone
Environmental Protection Section
Protective Sciences Division

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* Summer Student

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ABSTRACT

The "Total Data Reporting Accessory" available for the Beckman Metabolic Measurement Cart has characteristics which limit its use in a research laboratory. Storage of test results and retrieval for subsequent analysis is awkward. In addition, metabolic data from only one individual can be measured during a given test. This is a serious limitation when two or more persons participate in the same experiment. Software modifications which have been made to overcome these difficulties are described.

RÉSUMÉ

Dans un laboratoire de recherches, l'utilisation du "Total Data Reporting Accessory", qui est compatible avec le chariot de mesure métabolique de Beckman, est limitée en raison de certaines de ses caractéristiques. Ainsi, la mise en mémoire et le repérage ultérieur des résultats des essais pour fins d'analyse se révèle difficile. De plus, durant un essai, on ne peut mesurer les données métaboliques que d'une seule personne. Cela devient un problème sérieux pendant une expérience où participent plusieurs personnes. Les modifications apportées au logiciel pour régler ces difficultés sont décrites dans cet ouvrage.

INTRODUCTION

Measurement of metabolic rates has traditionally involved the use of gas meters, Douglas bags or spirometers to determine volume and a variety of chemical or physical methods to determine oxygen and carbon dioxide concentrations. These methods routinely required hours of time simply for collection of data and additional long periods for subsequent reduction and analysis of the data. During the past 15-20 years, the development of rapidly-responding gas analyzers, electronic gas volume sensors and relatively inexpensive electronic calcultors has led to the production of automated, self-contained systems for the measurement of metabolic rates.

One such system, the Beckman Metabolic Measurement Cart (MMC), is controlled by a programmable calculator and was described in detail by Wilmore et al. (1) in 1976. The MMC is a small, self-contained apparatus which includes analyzers or sensors for measuring oxygen, carbon dioxide, expired air volume and temperature, barometric pressure and time. An electronic interface digitizes the outputs of the various sensors and transmits them to a Monroe Model 1810 Programmable Printing Calculator which controls timing, performs measurements, makes the necessary calculations and prints the results on paper tape. Subsequently, the increasing availability of personal computers led to the introduction in 1981 of an accessory which includes a small computer interfaced to the MCC and software written in BASIC which automatically collects and stores metabolic data during a test, prints a report and plots selected variables in real time. Additional plots may be made immediately following a test.

Unfortunately, this system has characteristics which limit its use in a research laboratory. Firstly, although it is possible to store test results on computer tape for analysis later, a different tape cartridge is required for each new set of data. Otherwise data from a given test is overwritten when a subsequent test is performed. Secondly, metabolic data from only one individual can be measured during a given test. This is a serious limitation when two or more persons participate in the same experiment. This paper describes software modifications which have been made to overcome the above-mentioned difficulties. An example of how the modified system is used in our laboratory is also described briefly.

DESCRIPTION OF SYSTEM

The "Total Data Reporting (TDR)" accessory which was introduced by Beckman Instruments Inc.* in 1981 includes an HP-85 personal computer (BASIC operating system) and General Purpose Input/Output (GPIO) parallel interface (HP-82940A) (Hewlett-Packard Company) which is connected to the MMC using a special TDR cable and interface box. The HP-85 must be equipped with a 16 K Memory Module (HP-82903A) and if plotting on an external plotter is desired, an HP-IB Interface (HP-82937A) is also needed.

The TDR system must be used in conjunction with the "Clinical Exercise Testing Program", one of a number of programs for the MMC available from Beckman (SensorMedics). This program, stored on a series of eight magnetic cards, is entered into the Monroe calculator and desired operating conditions are selected on the MMC. Using this program, the MMC is operated in its normal fashion, remaining under control of the Monroe calculator.

The TDR is used only to collect and store data transmitted to it by the MMC at time intervals selected by the operator. Data is stored on magnetic tape in the internal tape drive of the HP-85. Personal information such as date of test, subject name, height and weight, medication, etc., some of which may be used in the calculation of certain metabolic variables, may be entered at the beginning of each test and is stored along with metabolic data. After all preliminary information is entered, the TDR system waits until the MMC is started and then begins to collect and store metabolic data.

At conclusion of a given test, the MMC is stopped and the operator can obtain graphs of a number of variables (e.g. oxygen consumption versus time, carbon dioxide production versus time, etc.) and can produce a complete printed report of the test. Data may also be stored on a different tape cartridge for subsequent analysis. After the desired number of graphs or reports is produced, the system is reset and another test may be conducted. If a different tape cartridge is not used for data storage, all of the data from the previous test is overwritten. For additional information see "Total Data Reporting Accessory, Operating Instructions" (2).

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* Currently supported by SensorMedics Corporation, Anaheim, California

METHODS

Of the more than twenty metabolic variables measured and/or calculated by the original TDR system, only seven are used routinely in this laboratory. These are:

- time of measurement (sec)
- minute volume (l/min)
- frequency of ventilation (breaths/minute)
- fraction of expired oxygen
- fraction of expired carbon dioxide
- oxygen consumption (ml/min)
- carbon dioxide production (ml/min)

The software was rewritten so that only these are considered. It was also decided that a maximum of four subjects would be monitored during any experiment (although this can be increased to any number, subject to hardware limitations).

The major differences between the original and the modified TDR system are shown in the flow charts in Figure 1. With each system, the "Clinical Exercise Testing Program" is first entered into the MMC's calculator and the desired operating conditions are selected. The TDR software is then loaded into the HP-85 and the operator responds to a series of questions which appear on the screen. In the modified system, the number of subjects is first requested (four or less). Each system then asks for personal subject information (e.g. name, height, weight, etc.). After the operator confirms that the information entered is correct, data file(s) are created and this information is stored.

The original TDR software was written so that data from only one subject is stored in a tape file on the HP-85's internal tape drive. To accomodate up to four subjects in one experiment, the system was modified so that a separate data file for each subject is created. In order to accomplish data transfers as quickly as possible, an external disk drive (HP 9895A) is used instead of the HP-85's internal tape drive. After the data file(s) are set up, a "Collecting" program is automatically loaded and the computer waits until data is received from the MMC.

During an experiment, metabolic measurements are made at 0.5, 1, 2 or 4-minute intervals, selected on the MMC console. Between measurements, the operator has the option of continuing, switching subjects or stopping data collection. If the "switch" option is chosen, all information from the current subject is first stored in the appropriate data file and then all previously-recorded data from the new subject is loaded from his file into the computer. The switching process takes about

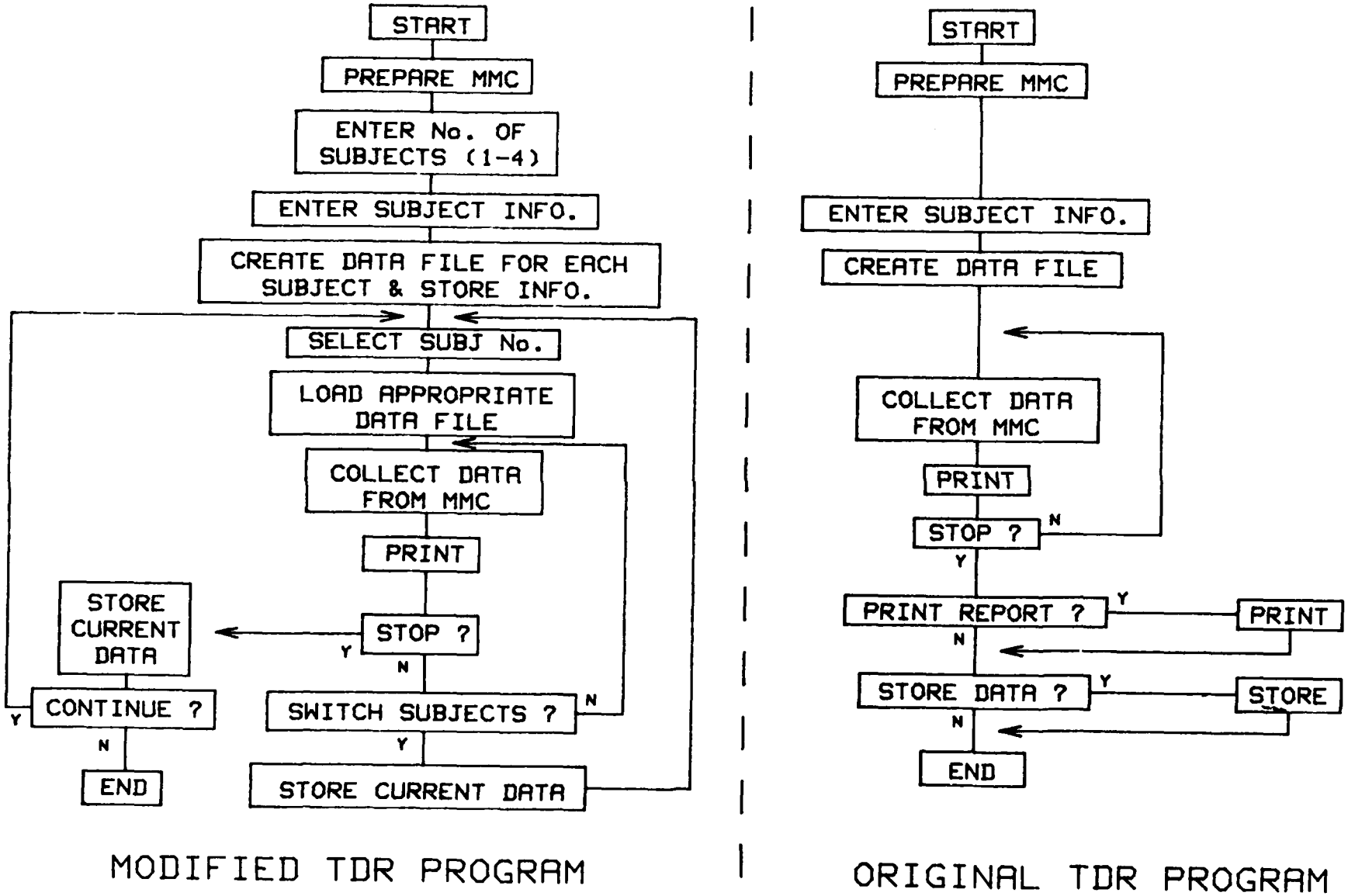

Figure 1: Flowcharts of modified and original TDR programs.

two minutes to complete, allowing expired air from the previous subject to clear the system. During this time, any data from the MMC is ignored. The clock measuring elapsed time during the experiment is not affected by the switching routine. If the "stop" option is chosen, the user has the option of either ending the experiment or resuming data collection later. If necessary, the experiment can continue with less than the total number of original subjects.

At the end of the experiment, the data files on disk are named "SUBJ1", "SUBJ2", etc. and should be renamed to allow for easier future reference and permanent storage.

RESULTS

The following is an example of an experiment in which the modified TDR program is used in our laboratory. Two volunteer test subjects dressed in protective clothing exercised on a treadmill for 50 minutes during which time metabolic rates and body temperatures were monitored. Since neither of these parameters vary rapidly, there was no requirement for continuous monitoring. We were thus able to use the TDR to measure the metabolic rate of both subjects for periods of eight minutes alternately throughout the duration of the experiment. A sample of the results obtained is given in Table 1.

Every two minutes metabolic measurements were made by the MMC and transmitted to the TDR system. The following parameters were printed and stored on disk: elapsed time (minutes), volume of air breathed (litres), rate of breathing (breaths per minute), oxygen consumption (ml per minute) and carbon dioxide production (ml per minute). During the actual experiment, results were printed sequentially every two minutes as the subjects were alternately monitored by the MMC. When the final results are printed, they appear grouped by subject in the format of Table 1.

DISCUSSION

Although the original TDR system is used to advantage in clinical applications, it was found that certain characteristics limited its use in

TABLE 1

Sample of Modified TOR Printout as Two Subjects
Exercise on Treadmill over 50-minute Period

Time (min)	Volume (l)	Rate (bpm)	O_2 Consumption (ml/min)	CO_2 Production (ml/min)	
2.1	26.9	23.4	1340	890	
4.1	25.6	21.1	1270	870	
6.2	29.1	22.2	1410	1010	
8.2	31.7	23.0	1430	1130	
18.2	33.6	23.7	1470	1210	Subject #1
20.3	33.2	23.4	1470	1210	06 Feb
22.3	33.6	24.2	1480	1220	Weight 58
24.3	33.7	23.7	1450	1220	Height 169
34.4	31.5	22.9	1400	1160	
36.4	34.4	25.4	1460	1230	
38.4	33.4	24.9	1430	1190	
40.4	33.9	25.2	1450	1210	
10.2	33.8	22.1	1270	1030	
12.2	35.0	24.1	1340	1120	
14.2	36.2	24.5	1340	1190	
16.2	38.1	25.2	1400	1270	
26.3	39.7	25.4	1410	1290	Subject #2
28.3	40.1	25.4	1400	1290	06 Feb
30.3	41.1	27.1	1420	1300	Weight 83
32.3	37.6	26.3	1280	1170	Height 185
42.5	36.6	25.5	1260	1140	
44.5	37.2	26.2	1260	1140	
46.5	35.9	25.9	1210	1090	
48.5	35.7	26.2	1210	1080	

research laboratory. The majority of physiological experiments performed in this laboratory involve comparisons between a number of different volunteer subjects under similar test conditions or tests on the same subject under various environmental conditions. Obviously, the ability to easily store and retrieve metabolic data collected by the system during any number of previous experiments is an important requirement. The ability to deal with more than one data set at a time (e.g. statistical analyses) is also desirable. In addition, experiments are often conducted simultaneously using more than one volunteer. A further requirement in this laboratory is the ability to collect metabolic data alternately from two or more subjects during an experiment, keeping the data from each separate while maintaining a common time base. The current supplier of the MMC (SensorMedics Corp.) was not able to provide software to support the above requirements, but encouraged DREO to modify the existing software.

The modified "Total Data Reporting" system described above is a reasonable solution to the problems identified at the beginning of this paper. It is used routinely in this laboratory. Subject information and metabolic data are stored on computer disk in a simple format and can be easily retrieved for further manipulation, plotting etc.

At present, the system is set up so that a maximum of 300 sets of seven measurements can be stored on disk in each of four different data files. With existing hardware this maximum can be increased approximately threefold. In many cases it would be advantageous to reduce this number, enabling data from additional experiments to be stored on the same disk and decreasing the time required to switch between subjects during an experiment. In either case, changing this number is a relatively simple exercise. Although the basic concept of the modifications which have been made is straightforward, a detailed listing of the actual changes to the program is not practical here. More detailed information may be obtained from the authors.

REFERENCES

1. J.H. Wilmore, J.A. Davis and A.C. Norton, "An Automated System for Assessing Metabolic and Respiratory Function During Exercise", J. Appl. Physiol. 40(4): 619-624, 1976.

2. "Total Data Reporting Accessory, Operating Instructions". Beckman Instruments Inc., FM-552753-301, 1981.

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